Valuing Crypto Assets

[DRAFT]

Abstract: This paper identifies three approaches to valuing Crypto Assets. We review the three approaches, 1) cost of production, 2) equation of exchange and 3) network value. We then propose a new model, modifying the cost of production. Given the growing popularity and value of the Crypto Asset market, we add to the growing academic and professional research.

Key Words: Crypto Assets, Crypto Currency, blockchain, bitcoin, value, ethereum, cost of production, equation of exchange, network value, Metcalfe's Law

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1.0 INTRODUCTION

There is a digital revolution taking place globally and words such as *blockchain* and *bitcoin*, which are hallmark terms of this revolution, are permeating all of modern culture. Born from this digital revolution is a new yet burgeoning asset class broadly referred to as Crypto Assets. The origin of Crypto Assets is approximately November of 2008, when a pseudonymous entity referred to as Satoshi Nakamoto released a whitepaper titled, *Bitcoin: A Peer-to-Peer Electronic Cash System.* This paper proposed a digital payment system that did not require a singular, trusted third party but rather a network of incentivized participants. Bitcoin is typically referred to as a Crytpo Currency. The underlying technology of Crypto Currencies is referred to as blockchain, and it is this technology that has propelled the growth of the Cypto Asset market. The blockchain has provided a new ability to build trusted decentralized products and services, with the intent of disintermediating many of the larger business and government agents which have unilaterally controlled most of society's information and wealth. These new products and services developed on the blockchain, yet which are not a Crypto Currencies, are referred to as Crypto Projects.

This Crypto Asset market is avant-garde and business plans so different than traditional business enterprises that it has created a need to reconsider the definitional concepts of revenue, expenses, capital, taxable income, profit, shareholders, stakeholders and value identification to name only a few. In this paper we consider the definition of value, and examine the currently proposed models to value Crypto Assets. We identify benefits and shortcomings of these models, propose modifications to improve the models, and then suggest additional considerations for future research.

This paper will progress in the following manner. First, we explain the major drivers of the Crypto Asset market and identify and explain each of the Crypto Assets and how they work, and also discuss the financing and public market for these assets. Next, we review the three most accepted valuation models currently in use and then explain the benefits and shortcomings to each. Third, we propose modifications and changes to the existing models and provide a detailed examination of how our model works. Last, we propose a future research agenda, and questions that researchers may consider as we further refine the models and develop a body of literature with substantial foundation.

2.0 EXPLAINING CRYPTO ASSETS

The Blockchain

To understand how the blockchain works can be quite difficult though a precursor for understanding how value is created by companies in the Crypto Asset marketplace. The following is an explanation of how the Bitcoin[1] blockchain works. It is important to note that all blockchains operate differently, however we explain the Bitcoin blockchain mainly due to the enormity of media attention as of the writing of this paper.

Unlike the traditional banking system, where a bank is trusted to maintain the ledger of transactions (single ledger), the record of ownership to digital assets in a blockchain are known by the entire population simultaneously (distributed ledger), removing the need to trust a single entity. Transactions are completed peer-to-peer and broadcast through open-source software to all computers[2] that maintain the distributed ledger. This distributed ledger is updated periodically and information on the distributed ledger is saved in periods of time, typically referred to as a block (block of time), and chained together through cryptography. Blocks are created when a miner[3] solves a difficult mathematical problem. To solve these problems, miners employ computers that require a substantial amount of processing speed and a significant amount of electrical power. We refer to this as computational power. Upon successfully solving the mathematical problem, the miner will broadcast their solution to the nodes and now has proof of its work. Once the nodes recognize that the problem was solved and confirm that all information on the block is valid, the block is created, and chained to the previous block. Since there is no central government authority issuing bitcoins (such as the Federal Reserve), the underlying blockchain software is programmed where after each block is created, the miner who solved the underlying mathematical problem is rewarded with newly created bitcoin.

The Bitcoin protocol targets creating blocks every 10 minutes, on average[4]. This is done by using what is referred to as the *difficulty algorithm.* If the mathematical problems are solved in less than ten (10) minutes, the *difficulty* of the mathematical problem increases, and if the block takes longer than ten (10)

[1] NOTE: In this paper we use bitcoin, lower case b to represent the crypto currency, and Bitcoin, upper case B to represent the Bitcoin protocol.
[2] NOTE: These computers are also referred to as nodes, but for purposes here we will refer to them as simply computers.
[3] NOTE: A miner is a computer which organizes transactions into chronological order. These computers are tasked with solving a resource intensive math problem and, if they do, are rewarded in coins. This process is similar to that of a gold miner that needs to run machinery to "mine" gold from the Earth and are rewarded with Au or gold.

[4] NOTE: Other protocols, such as Ethereum, target a much faster creation protocol.

minutes, the difficulty is decreased. The mathematical problem is constructed so computational power is required to solve it. This is designed so that the miners[5] have an economic cost associated with working on the blockchain, and will be incentivized to operate based on the rules of the protocol. Should a miner attempt to break the rules, they will lose the opportunity to win the bitcoin. As miners incur energy costs, they will seek profit by winning bitcoins by way of block rewards and transaction fees. As miners accumulate bitcoin they can do two things with it. They can sell their bitcoin on a crypto exchange, such as Coinbase, sell their bitcoin directly to another individual, or hold it in anticipation of bitcoin increasing in value. Because of this, miners are aligned with the success of the Bitcoin protocol and are aligned with further development and wide adoption of its use.

Crypto Assets

With so many new terms and references, it can be confusing to follow the Crypto Asset market. To help understand how this works consider the following. The blockchain is the technology infrastructure and Crypto Assets are the native tokens created to be used over the blockchain. As explained earlier, Crypto Assets can be delineated into Crypto Currencies, Crypto Commodities and Crypto Projects. A Crypto Currency is a digital asset that acts predominately as a medium of exchange, unit of account, and store of value. While Crypto Currencies act as a means to transmit monetary value, Crypto Commodities are digital assets used as inputs to perform services or create finished goods. For example, cloud storage and online bandwidth are two examples of digital commodities that help to provision a service. This is similar to a traditional commodity such as oil which can is typically used to power machinery. In an ever more digital economy, there is a need for Crypto Currencies to serve as a means to transmit monetary value and Crypto Commodities to power the creation of digital finished goods. Last, Crypto Projects are the digital finished goods and services. As applications are built using the blockchain, Crypto Projects are needed as a consumer-facing digital asset. Similar to how traditional applications are built using Apple IOS or Android, Crypto Projects are built on top of Ethereum or a similar protocol. Although Bitcoin is a protocol, the original creators did not allow any development on top of it. There are presently over 1,000 Crypto Assets actively trading on exchanges and at the time of writing worth over $500 billion[6].

Financing Crypto and the New Challenges

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[5] NOTE: In this context we are talking about the shareholders of the company who has the computers employed, and who are using these computers to mine.

[6] "Cryptocurrency Market Capitalizations", https://coinmarketcap.com/, December 10, 2017.

Today, most entrepreneurs raise capital for their companies in the form of angel, venture and/or friends and family capital. Most of these capitals are invested directly into the company seeking the capital, and in return for the investment, these investors most often receive equity and/or notes in return.

As entrepreneurial companies mature, many of them continue to raise capital in subsequent rounds of equity or debt sales. While for some companies this continues indefinitely with growth, others become cash flow sustainable and have no need for additional financing. For many entrepreneurs and shareholders (generally speaking – but not including everyone) the ultimate event is a successful sale of the company in the public stock markets or by sale in a private transaction. With the evolution of blockchain technologies, there is a new type of financing emerging giving entrepreneurs a different avenue to raise capital. Will this new financing mechanism be sustainable is unclear but for the short term it is something to consider.

Although many Crypto Assets have raised equity and debt capital from angel, venture, crowdsourcing and friends and family, they have relied mostly on a new form of financing typically referred to as an ICO (initial coin offering) or token sale. The token sale is a process where a Crypto Asset company creates a digital asset called a token, and then sells the tokens to **investors** or **future users** of the company's services. In exchange for the token, the issuing company receives bitcoin or ether, mainly for development purposes.

Although it is very early in the evolution of the token sale, many Crypto Asset companies using this form of financing have typically raised capital selling one of three types of tokens. Tokens are usually referred to as **utility, security** or **hybrid tokens**. Utility tokens are tokens that provide the purchaser access to a good or a service, which in most situations, have yet to be developed. Many times utility tokens provide the user the opportunity to gain access to some online platform, or may entitle them to special privileges or deals on future goods and services offered by the company or it may provide them a mechanism for exchanges. A security token is different and resembles something like a common stock, where token holders may have rights to future profits or sales of the company, or perhaps liquidation preferences and or other rights. In many instances, security tokens have rights that are similar, but most often inferior, to rights afforded the debt or equity holders. The last type of token is the hybrid, which has attributes associated with utility and security tokens. Although we do not address the issue within this paper, the Securities and Exchange Commission and the Internal Revenue Service, among other government authorities have expressed interest in how tokens are defined.

Token Marketplace

A distinguishing feature of tokens is with respect to liquidity. Most often, an early investor or debtor in a private company has limited ability to sell their equity or debt to another party. Unlike these traditional forms of capital, most often, companies issuing tokens list their tokens on a public exchange, such as Bitfinex, Poloniex, Kraken, Gemini, Hitbtc, and Gdax. Because of this, token owners can sell their tokens over the exchange at the market price. This applies for most Crypto Assets.

Token Buyers and Investors

There are three types of token buyers. There is the buyer who purchases a token for access to a company's software or services or future use as a commodity or medium of exchange. Second, there is the buyer who anticipates an increase in the token's value and so is looking for a return on investment. This return may be in the form of periodic benefits or some gain on an exit event. Lastly, there are buyers who hope to accomplish both goals simultaneously.

Additionally and not dissimilar to early stage companies granting stock options or shares to employees and partners, many companies issuing tokens do the same thing, but rather than issuing shares they are granting tokens. Many times these tokens are granted at once and other times they vest over a period of time. This new phenomenon of selling or issuing tokens and the subsequent ability to sell these tokens on a public exchange creates a host of valuation issues for the issuing company, the owner of the token and future token holder. A few often overlooked valuation issues include but are not limited to the value of the token on gift or grant to the employee, the value of the token during an exchange, the value of tokens for the future buyers, and the value of tokens in a hypothetical acquisition. Other considerations that have not been given their due in the literature is with respect to valuing tokens for IRS tax reporting purposes, or for FASB financial reporting purposes – each of which will probably encompass its own body of valuation research.

Underlying each of these purchasing decisions is an inquiry into value. Is the company selling the initial token at the right price? Is the buyer of the token on the secondary market purchasing the token at an inflated or deflated price? Unlike the equity or debt markets where financial models such as the discounted cash flow model or capitalization of earnings model have been broadly adopted there is almost no consensus on how tokens can and or should be valued. It is these questions which we now turn.

3.0 EXISTING MODELS

There is an emerging body of industry insights and economic research associated with valuing Crypto Assets, with a major portion of the research focused on valuing bitcoin or ether. Most of these insights and research come from academics, though some of the research comes from the financial services community, and although less common, a smattering of the insight comes from a small group of blockchain sub-culturalists. Based on a detailed literature search, we have found three approaches to valuing Crypto Assets: (1) cost of production, (2) value as a currency and (3) the value as a network. We review each approach below.

Cost of Production Approach

Adam Hayes, a Ph.D. student at The New School for Social Research has produced a series of empirical papers[7] on valuing Crypto Assets. The observations from his research suggest that there are three (3) variables that can determine approximately 84% of the value of Crypto Assets: (1) computational power, (2) rate of coin production, and (3) the relative difficulty of the mining algorithm. Hayes proposes that according to microeconomic theory, the marginal cost of mining bitcoin should equal the marginal cost, which should equal the price.[8]

Hayes suggests that bitcoin has intrinsic value. While bitcoin is intangible, it has similar attributes to traditional commodities, such as labor value. Mining for bitcoin requires the use of electricity to win bitcoins which can be viewed similarly to running an oil rig in search for oil. Hayes states that "instead of approaching bitcoin as a digital money or currency, it is perhaps more appropriate to consider it a virtual commodity with a competitive market against producers."[9] Hayes argues that the more mining power employed the more acceptance of the Crypto Asset. A Crypto Asset with no acceptance or usage will have neither value nor computational power directed at it. A rational miner would only employ mining resources if profitable, and therefore if the marginal cost of mining exceeded the marginal revenue of mining, that miner would redeploy resources and thus removing computational power from the network.

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[7] SOURCE: "What Factors Give Cryptocurrencies Their Value," Adam S. Hayes, March, 2015: "Cryptocurrency Value Formation: An Empirical analysis leading to a Cost of Production Model for valuing bitcoin," Hayes, Adam, May 2016; "Bitcoin price and its Marginal Cost of Production: supporting evidence," Adam S. Hayes, September 2017.

[8] SOURCES: *ibid, pp.1-21.*

[9] SOURCE: *ibid, p. 13.*

According to Hayes, any opportunities for excess returns are short-lived as competition drives down profit. This is based on two forces, 1) Miners seek and mine for the most profitable coin which raises the aggregate network hashing power[10] in that coin, causing the *difficulty* to increase. 2) As the *difficulty* increases, profitability falls per unit of mining effort and the market exchange rate will change as mining participants actively produce and subsequently sell relatively overpriced coins.

The variables in Hayes' formula are: 1) the cost of electricity, measure in cents per kilowatt-hour; 2) the energy consumption per unit of mining effort, measured in watts per GH/s; 3) the monetary price of bitcoin in the market; and 4) the difficulty of the bitcoin algorithm. Using established microeconomic theory, the marginal product of mining should theoretically equal its marginal cost in competitive markets, which should also equal selling price. Therefore, Hayes proposes the following formula,

$$\$P = E_{day} / BTC / day,$$

where,
***\$P** is expressed in dollars per bitcoin,*
***E_{day}** is the cost of mining per unit of mining power per day, and*
***BTC/day** is the expected number of coins to be mined per day on average per unit of mining power.*

Hayes applies this formula in his 2017 paper, back-testing the model using historically observed bitcoin price data as compared to what the implied model price would have been at the time. After completing a multi-variable ordinary least squares regression, he suggests that nearly 92% of bitcoin's observed market price can be explained by the cost of production model. To understand causality, Hayes relies on a Granger Test[11][12], and finds that the cost of production model predicts market price.[13]

Valuing a Crypto Asset as a Currency

In *Cryptoassets: The Innovative Investors Guide to Bitcoin and Beyond,* co-author Chris Burniske proposes valuing Crypto Assets using the Equation of Exchange formula, originally developed by Irving

[10] NOTE: Hashing power is the aggregate computational power being applied to the network at a given time. It is also referred to as mining effort, hashrate, or hashpower.

[11] NOTE: A Granger test is a statistical hypothesis test for determining whether one time series is useful in forecasting another.
[12] SOURCE: "Investigating Causal Relations by Econometric Models and Cross-spectral Methods", Granger, C. W. J.,1969, pp. 424–438.
[13] SOURCE: "Bitcoin price and its marginal cost of production: supporting evidence," Adam S. Hayes, September 2017, pp. 6-9.

Fisher[14]. This equation was originally developed to predict the value of a currency based on the acceptance and speed of economic transactions in the macro-economy. The equation of exchange is commonly seen as the formula, MV=PQ, however Burniske argues that a Crypto Asset valuation is largely comprised of solving for M, and thus the formula is rearranges as follows,

$$M=PQ/V,$$

where,
***M** = size of the monetary base necessary to support a cryptoeconmy of size PQ, at Velocity V,*
***V** = velocity of the asset,*
***P** = price of the digital resource being provisioned, and*
***Q** = quantity of the digital resource being provisioned.*

Burniske, in his model conducts a total addressable market (TAM) analysis, used typically in traditional finance for analyzing start-up companies. A TAM analysis is a top-down approach to value, starting with the total size of a market and attempting to ascertain what share of the market the specific asset being valued will obtain. To value bitcoin, Burniske emphasizes the importance of determining the size of the addressable market, what share bitcoin will take from that market, what bitcoin's velocity will be, and what the appropriate discount rate is.[15]

Using bitcoin as an example, we can assume that bitcoin services the entire remittances market of $500 billion and had a velocity of 5. Dividing $500 billion (PQ) by a velocity of 5 (V) would yield a total value of bitcoin of $100 billion (M). If we assumed 21 million coins outstanding, then the value per each bitcoin would be $4,762. Burniske also argues that bitcoins value is additive depending on the number of use cases it serves. For example, the global gold market is worth $2.4 trillion and bitcoin were to take 10% market share, then it would need to store $240 billion of value. Holding bitcoin as digital gold has a velocity of 1 because there is minimal turnover, thus $240 billion/1=$240 billion. Once again assuming 21 million coins, then each bitcoin would need to store $11,430 of value to meet the demand of 10% of the investable gold market. Considering this, if bitcoin were to act as a digital goal and represent the remittances market, then the values would need to be added, $4,762 + $11,430 = $16,192 per each bitcoin.[16]

Valuing a Crypto Asset as Network

[14] SOURCE: [5] SOURCE: "David Hume and Irving Fisher on the Quantity Theory of Money in the Long Run and the Short Run" Dimand, Robert W, (2013) *European Journal Of The History Of Economic Thought* 20, no. 2: 284-304.
[15] SOURCE: *ibid*, p. 178.
[16] SOURCE: "CryptoAssets: The Innovative Investor's Guide to Bitcoin and Beyond," Chris Burniske & Jack Tatar, -McGraw-Hill, 2018, pp. 174-179.

The third method for valuing Crypto Assets uses a theorem proposed by the founder of Ethernet, Robert Metcalfe. Metcalfe proposed that the value of a network is proportional to the square of the nodes, or users on the network multiplied by . Research conducted suggests that the relationship when applied to large social networks may be accurate. Metcalfe attempted to validate his findings in a 2013 paper using Facebook as a proxy. The theory is that a network has little or no value with just one or two users, however with each new user, the utility value of the network more than doubles.

In his paper *Digital Blockchain Networks Appear to be Following Metcalfe's Law*, Ken Alabi Ph.D. suggests that the value of bitcoin can be measured by relying on Metcalfe's Law. Alabi uses three (3) different Crypto Assets as examples, Bitcoin, Ethereum, and Dash.[17] Alabi suggested using the number of unique addresses participating daily in the network as a proxy for the relative number of active users on the network. Alabi proposed a variation of Metcalfe's Law, based on the exponent of the root of the number of active users. Using past Crypto Asset data, Alabi shows that historical market prices do in fact follow the model.[18]

In addition to Alabi's research, FundStrat's co-founder Tom Lee (Lee), a former strategist at J.P. Morgan uses a similar method. Lee stated in a recent interview with Business Insider that, "If you build a very simple model valuing bitcoin as the square function of the number of users multiplied by the average transaction value, 94% of the bitcoin movement over the past four years can be explained by that equation."[19] The following is a formula for calculating the value of bitcoin.

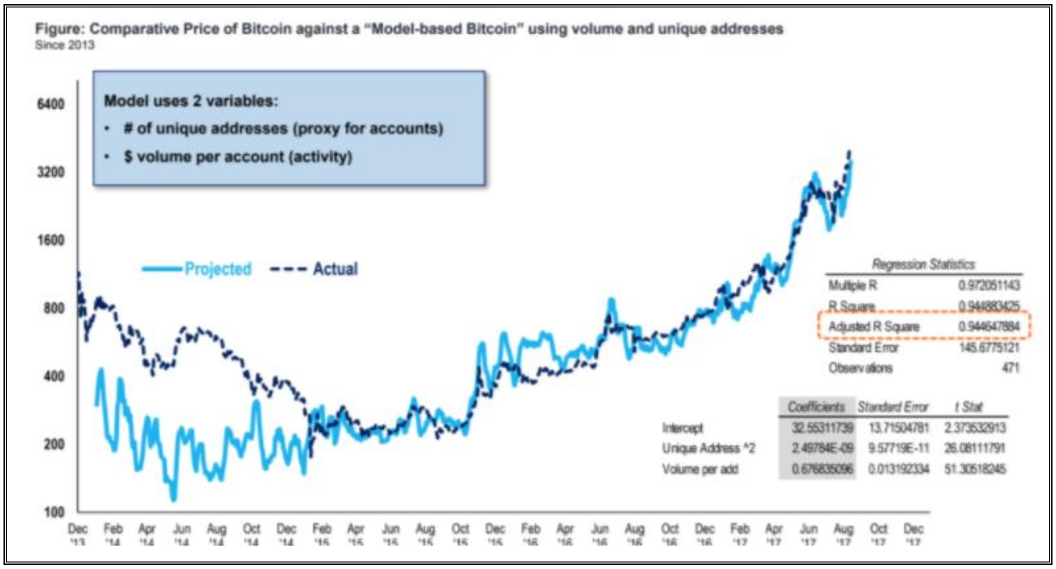
Value of bitcoin = Unique Addresses^2 ** $ volume per account*

Where,
Unique Addresses represent the number of unique bitcoin addresses participating on the network per day
$ volume per account represents bitcoin transaction volume per day

We present a graph created by Lee below which displays the relationship between his model's outcome and that of the market price of bitcoin.

[17] SOURCE: "Digital Blockchain Networks Appear to be following Metcalfe's Law" Alabi, Ken, 2017, pp.23-29.
[18] SOURCE: *ibid, pp.23-29.*
[19] SOURCE: "Bigger than Bitcoin," Business Insider, http://www.businessinsider.com/bitcoin-price-movement-explained-by-one-equation-fundstrat-tom-lee-metcalf-law-network-effect-2017-10.

Figure 1: Fundstrat Comparative Bitcoin vs Model-based Bitcoin Price[20]



4.0 PUSHING THE MODEL FORWARD

As explained above, bitcoin can be valued similar to a commodity, currency or network. However we believe that bitcoin, in its current form, is not an effective medium of exchange since fees for small transactions can at times be larger than the value of the transaction itself. Because of this, bitcoin is not an effective currency today in the traditional sense and so valuing it as a currency does not seem appropriate. Valuing a network using Metcalfe's law is an intriguing approach that in our opinion solves for **price rather than value s**ince the model only applies two variables, average transaction value and number of unique addresses and it does not consider the impact that costs have on value.

We suggest that Hayes' approach to valuing bitcoin is the most appropriate model based on the above commentary but his model can be enhanced with forecasting future variables. We have attached our

[20] SOURCE: "Bigger than Bitcoin," Business Insider, http://www.businessinsider.com/bitcoin-price-movement-explained-by-one-equation-fundstrat-tom-lee-metcalf-law-network-effect-2017-10.

model with preliminary assumptions and we provide a multi-year view into the value of bitcoin based on growth and risk. Our model begins on January 1, 2018 and ends on December 31, 2029.

We present this model in Exhibit A. Our approach is to create a forward looking Marginal Cost of Production model by forecasting key assumptions such as energy efficiency, cost of electricity, difficulty and then discounting the value to the present. In forecasting the assumptions, we looked to historical trends while recognizing that more research is needed. In Exhibit B, Cell E4 through P4, the bitcoin miner reward is displayed. Every four years, the bitcoin block reward halves (halving) as per the Bitcoin Protocol[21]. This is an input in calculating the expected BTC per day. Next we make assumptions to forecast energy efficiency, cost of electricity, and aggregate hash rate growth.

With respect to the cost of electricity, we looked at U.S. CPI data dating back to 1978 which can be viewed in Exhibit B. We found that the electricity price per kWh in the U.S. has grown at a 2.9% compound annual growth rate (CAGR) from 1978 to 2017. We assume this growth rate into the future, as shown in Exhibit A, cell B6.

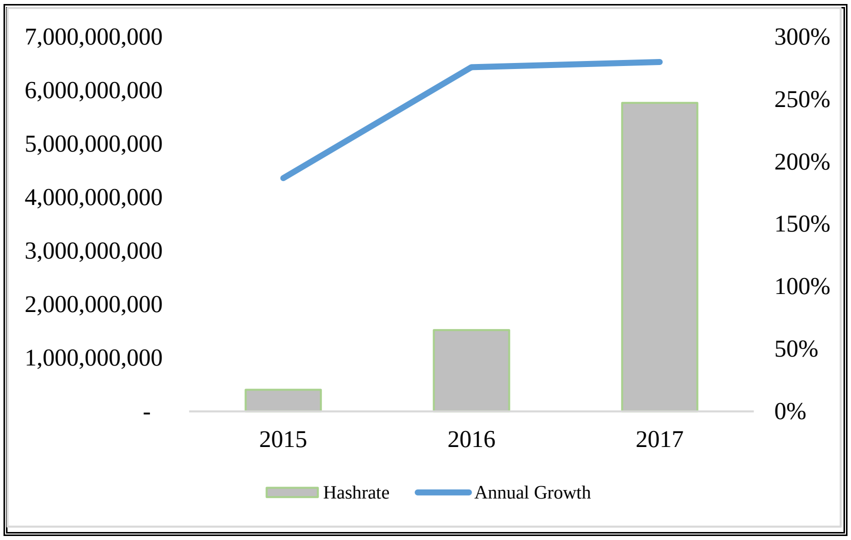
We next forecast energy efficiency, also referred to as energy consumption per unit of mining effort, as measured in watts per GH/s (gigahashes per second). In Figure 1 of Hayes' 2016 paper, a graph of Bitcoin Mining Efficiency is shown from 2009-2016. In 2010, bitcoin mining was conducted primarily using GPU (Graphics Processing Unit) which had efficiency of 455 watts per GH/s. Presently ASICs (Applied-specific integrated circuit) have been designed specifically for bitcoin mining, and operate at an efficiency of .20 watts per GH/s. Considering this, we can calculate that efficiency has improved by 66.9% yearly from 2011-2017, [$((.20 / 455)^{(1/7)} - 1)$ =66.9%[22]] This efficiency improvement is faster than what would be suggested by Moore's Law, which is the observation that the number of transistors in a dense circuit board double every two years. In our model, we assume a 50% increase in efficiency per year (Exhibit B, cell B6), consistent with Moore's Law as the advent of ASICs will likely slow the pace of efficiency increase.

[21] SOURCE: "Understanding Bitcoin: Cryptography, Engineering and Economics" Franco, Pedro, October, 2014. Wiley.

[22] SOURCE: "Cryptocurrency Value Formation: An empirical analysis leading to a cost of production mode for valuing Bitcoin," Adam S. Hayes, May 2016, Figure 1, p. 19.

Bitcoin's difficulty algorithm is one of the more challenging assumptions to forecast. The difficulty algorithm is a function of the aggregate hash rate sent to the network, or computational power. As previously mentioned, the higher the hash rate, the more acceptance of the coin, and thus a higher value can be inferred. We look to historical annual growth rates of bitcoin's aggregate hash rate, which can be viewed in the graph below. The yearly growth rate of approximately 275% for the past two years demonstrates the maturing of bitcoin. Yearly growth rates typically decline for new market entrants as they mature, whether it would be revenue growth for a startup or the growth in an economy. Hash rate annual growth rates for 2013 and 2014 were 9,339% and 9,428% respectively. Since then, the annual growth rate has declined to 187% in 2015 and is presently 280%. Given the technical innovation in ASIC mining hardware, it is probable that the annual growth rate of aggregate hash rate will decrease after 2018. In Exhibit B, Cell F9 we assume a 300% starting growth rate in 2018 and cut that rate by 10% (Cell B8) yearly.

Graph 1: Annual Hash Rate Growth (bitcoin)



After applying these assumptions, we calculate the two main components of the formula, cost of mining per day and expected BTC per day, consistent with Hayes' method. Cost of mining per day is calculated as [watts per GH * $/kWh] which we show in cell E10 in Exhibit B for 2017. After calculating cost of mining per day, the expected BTC/day is calculated using the formula, [((Sec/day) / (difficulty* 2^{32} / 1,000,000,000,000))*block reward], where,

Sec/day = is a constant representing seconds in a day (86,400),
Difficulty = the forecasted Bitcoin difficulty (Cell E9)
2^{32} represents the normalized probability of a single hash[23] *solving a block as an attribute to the mining algorithm*
1,000,000,000,000 is a constant for converting difficulty into Tera hash/second
Block reward is the reward miners receive per block (Cell E4)

We can condense the formula to the average cost of mining per day divided by the average expected bitcoins received per day which equals the value of bitcoin (cell E12 for 2017). As shown in Exhibit B, Cell G12, the value of bitcoin in 2019 is [.1714/.000021033 = $8,149].

After applying these assumptions, we also apply a discount rate. A 40.0% compounded discount rate was applied to the future value of bitcoin prices. We use a 40.0% discount rates mainly because this is a discount rate typically associated with venture capital projects. In Exhibit B, Cell B11, we input the 40.0% discount rate and the annualized discount rates are on row 16. In Cells E16 to P16, we display the discounted value per year. According to our model, the price of one bitcoin per U.S. dollar would be worth $472,608

[23] NOTE: A hash function is a mathematical process that takes input data of any size, performs an operation on it, and returns output data of a fixed size. Hash functions are used as the inputs to solving a block.

in 2029, yet discounted to the present would be $13,809 on January 1, 2018 (hypothetical day), indicating that bitcoin is over valued at the time of writing this paper with bitcoin currently trading at approximately $17,000. The value of bitcoin in 2029 is based on substantial changes in the market over the next eleven (11) years.

In this paper, we have proposed and calculated the present value of bitcoin using a forecasted cost of production model. We believe this model can be used to value any Crypto Asset based on a hypothetical exit period. Our work largely follows the efforts of Adam Hayes, and attempts to further his research. Our proposed formula for valuing any Crypto Asset is as follows,

$$\$PV = (X_{day} / EC_{day}) / (1 + r)^{n}$$

where,
$PV = Present value of a Crypto Asset ,
X_{day} *= Cost of mining per unit of mining power per day,*
EC_{day} *= Expected coins received per unit of mining power per day,*
r = discount rate
n = number of periods

5.0 CONCLUSION

While this model is useful in starting the conversation pertaining to bitcoin's value, it is only as good as the assumptions used within. Given the nascent nature of this asset class, we believe much work is needed, and that economists and financial professionals have only begun to understand the complexities in valuing Crypto Assets. Future research is necessary to develop further a comprehensive model to value Crytpo Assets. Research with respect to forecasting input variables are paramount, especially understanding and forecasting hash rate growth. Along with understanding growth, additional research is required to quantify risk of Crypto Assets. In order for the Crypto Asset market to gain broad adoption it is important that research continue to expand with as much or even more vigor than research in the traditional markets.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	**Exhibit A**															
2																
3					**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**
4				**Block Reward (BTC)**	12.5	12.5	12.5	12.5	6.25	6.25	6.25	6.25	3.125	3.125	3.125	3.125
5	**Energy Efficiency W per GH (Annual Growth)**	**-50.0%**		**Energy Efficiency**	**0.2**	0.100000	0.050000	0.025000	0.012500	0.006250	0.003125	0.001563	0.000781	0.000391	0.000195	0.000098
6	**Cost of Electricity $/kwh (Annual Growth)**	**2.9%**		**Cost of Electricity $/kwh**	**$ 0.135**	$ 0.139	$ 0.143	$ 0.147	$ 0.151	$ 0.155	$ 0.160	$ 0.164	$ 0.169	$ 0.174	$ 0.179	$ 0.184
7				**Hashrate (GH/s)**	5,770,057,182	23,080,228,729	85,396,846,297	292,911,182,799	933,507,939,579	2,770,931,617,053	7,679,553,848,715	19,923,243,179,459	48,510,919,531,504	111,158,000,087,287	240,352,660,337,522	491,770,032,378,640
8	**Rate of Change of Hashrate Growth**	**10.0%**		**Growth**		**300%**	**270.0%**	**243.0%**	**218.7%**	**196.8%**	**177.1%**	**159.4%**	**143.5%**	**129.1%**	**116.2%**	**104.6%**
9				**Difficulty**	807,808,005,512	3,231,232,022,048	11,955,558,481,578	41,007,565,591,812	130,691,111,541,106	387,930,426,387,465	1,075,137,538,820,070	2,789,254,045,124,300	6,791,528,734,410,530	15,562,120,012,220,100	33,649,372,447,253,100	68,847,804,533,009,600
10		**Discount Rate**		**Marginal cost of mining per day**	$ 0.648	$ 0.333	$ 0.171	$ 0.088	$ 0.045	$ 0.023	$ 0.012	$ 0.006	$ 0.003	$ 0.002	$ 0.001	$ 0.000
11		**40.0%**		**BTC received/ day**	0.000311283	0.000077821	0.000021033	0.000006132	0.000000962	0.000000324	0.000000117	0.000000045	0.000000009	0.000000004	0.000000002	0.000000001
12				**Value**	$ 2,082	$ 4,283	$ 8,149	$ 14,376	$ 47,127	$ 71,946	$ 102,550	$ 136,830	$ 342,699	$ 403,865	$ 449,124	$ 472,608
13																
14				**Time**		*0.5*	*1.5*	*2.5*	*3.5*	*4.5*	*5.5*	*6.5*	*7.5*	*8.5*	*9.5*	*10.5*
15				**Discount Rate**		**118%**	**166%**	**232%**	**325%**	**455%**	**636%**	**891%**	**1247%**	**1746%**	**2445%**	**3423%**
16				**Discounted Value**	$ 2,082	$ 3,619	$ 4,920	$ 6,199	$ 14,515	$ 15,828	$ 16,115	$ 15,359	$ 27,476	$ 23,129	$ 18,372	$ 13,809

CPI-Average Price Data

Series Id: APU000072610

Series Title: Electricity per KWH in U.S. city average, average price, not seasonally adjusted
Area: U.S. city average
Item: Electricity per KWH
Years: 1978 to 2017

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
1978											0.046	0.046	0.046
1979	0.046	0.047	0.047	0.048	0.049	0.052	0.053	0.053	0.053	0.053	0.051	0.052	0.050
1980	0.053	0.055	0.056	0.056	0.058	0.063	0.064	0.064	0.065	0.063	0.061	0.062	0.060
1981	0.063	0.064	0.065	0.066	0.067	0.071	0.073	0.075	0.074	0.072	0.071	0.071	0.069
1982	0.073	0.073	0.075	0.075	0.075	0.079	0.079	0.079	0.079	0.077	0.074	0.075	0.076
1983	0.075	0.075	0.076	0.075	0.077	0.081	0.082	0.082	0.082	0.080	0.077	0.077	0.078
1984	0.078	0.079	0.079	0.080	0.081	0.086	0.087	0.089	0.084	0.081	0.079	0.078	0.082
1985	0.079	0.079	0.079	0.080	0.080	0.085	0.085	0.085		0.082	0.080	0.080	0.081
1986	0.081	0.075	0.075	0.074	0.074	0.080	0.080	0.080	0.080	0.074	0.073	0.073	0.077
1987	0.075	0.076	0.076	0.076	0.076	0.084	0.084	0.085	0.084	0.078	0.077	0.077	0.079
1988	0.078	0.078	0.078	0.077	0.077	0.084	0.084	0.084	0.084	0.080	0.078	0.078	0.080
1989	0.079	0.079	0.079	0.079	0.080	0.086	0.086	0.086	0.086	0.081	0.080	0.081	0.082
1990	0.081	0.081	0.081	0.082	0.082	0.088	0.087	0.087	0.088	0.083	0.082	0.082	0.084
1991	0.084	0.084	0.085	0.084	0.085	0.090	0.091	0.090	0.091	0.087	0.084	0.085	0.087
1992	0.085	0.084	0.086	0.086	0.087	0.092	0.092	0.091	0.092	0.088	0.086	0.088	0.088
1993	0.089	0.087	0.088	0.088	0.090	0.094	0.095	0.097	0.097	0.093	0.091	0.090	0.092
1994	0.090	0.090	0.089	0.088	0.090	0.095	0.095	0.096	0.096	0.093	0.091	0.091	0.092
1995	0.091	0.091	0.091	0.090	0.092	0.098	0.098	0.098	0.097	0.094	0.092	0.091	0.094
1996	0.091	0.091	0.092	0.092	0.092	0.096	0.099	0.099	0.099	0.095	0.092	0.092	0.094
1997	0.092	0.092	0.093	0.092	0.093	0.099	0.099	0.098	0.099	0.093	0.092	0.090	0.094
1998	0.086	0.085	0.085	0.085	0.086	0.091	0.091	0.090	0.089	0.086	0.084	0.084	0.087
1999	0.084	0.084	0.084	0.084	0.085	0.089	0.090	0.089	0.090	0.087	0.085	0.085	0.086
2000	0.084	0.085	0.085	0.085	0.085	0.090	0.091	0.091	0.091	0.088	0.086	0.086	0.087
2001	0.088	0.088	0.089	0.089	0.090	0.097	0.099	0.098	0.097	0.093	0.090	0.090	0.092
2002	0.089	0.089	0.089	0.088	0.089	0.095	0.095	0.095	0.095	0.091	0.089	0.089	0.091
2003	0.089	0.089	0.089	0.091	0.092	0.097	0.098	0.098	0.098	0.093	0.090	0.090	0.093
2004	0.091	0.091	0.091	0.091	0.093	0.099	0.099	0.100	0.099	0.094	0.092	0.092	0.094
2005	0.094	0.094	0.094	0.095	0.097	0.104	0.105	0.105	0.106	0.102	0.102	0.102	0.100
2006	0.108	0.108	0.109	0.109	0.110	0.118	0.118	0.118	0.118	0.112	0.110	0.110	0.112
2007	0.113	0.113	0.113	0.113	0.115	0.122	0.122	0.121	0.121	0.117	0.115	0.115	0.117
2008	0.116	0.116	0.116	0.118	0.120	0.128	0.131	0.132	0.130	0.126	0.123	0.124	0.123
2009	0.126	0.126	0.126	0.125	0.126	0.132	0.131	0.130	0.130	0.126	0.124	0.124	0.127
2010	0.124	0.123	0.125	0.126	0.127	0.132	0.133	0.133	0.132	0.127	0.125	0.125	0.128
2011	0.125	0.125	0.127	0.127	0.129	0.134	0.135	0.135	0.135	0.130	0.128	0.127	0.130
2012	0.128	0.128	0.127	0.127	0.129	0.135	0.133	0.133	0.133	0.128	0.127	0.127	0.130
2013	0.129	0.129	0.128	0.128	0.131	0.137	0.137	0.137	0.137	0.132	0.130	0.131	0.132
2014	0.134	0.134	0.135	0.131	0.136	0.143	0.143	0.143	0.141	0.136	0.134	0.135	0.137
2015	0.138	0.138	0.136	0.137	0.137	0.143	0.142	0.142	0.141	0.136	0.134	0.133	0.138
2016	0.134	0.134	0.134	0.134	0.133	0.138	0.139	0.139	0.139	0.134	0.131	0.133	0.135
2017	0.134	0.135	0.134	0.135	0.137	0.142	0.143	0.142	0.142				0.138
													2.9%